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THE INFLUENCE OF OBSERVER EFFORT ON THE NUMBER OF INDIVIDUAL BIRDS RECORDED ON CHRISTMAS BIRD COUNTS

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Observer effort affects the results of all counts, surveys, and censuses. Observer effort is strictly controlled in the roadside surveys of the United States Fish and Wildlife Service: the Woodcock Singing-grounds Survey, the Mourning Dove Call-count Survey, and the Breeding Bird Survey. Differences in observer effort may affect the results of atlases and checklists, spot-mapping censuses, banding studies, raptor migration counts, and counts of breeding colonial waterbirds. The purpose of this paper is to suggest a new method of compensating for the effects of observer effort on the results of Christmas Bird Counts. Our method relies on empirically determining a species-specific relationship between effort and the number of individuals reported and using that relationship to estimate the number of individuals that would have been reported for a particular location in a particular year if the effort had been standardized. Our method is similar to the one used by Lack (1986) for the atlas of wintering birds in Britain and Ireland.

Measures of Effort on CBCs

It was realized early on that effort affected the number of individual birds recorded on Christmas Bird Counts (CBCs). Thus, effort has been reported consistently, at least since the early 1950s. Effort on CBCs has been measured traditionally in party-hours and party-miles; in addition, the number of observers is recorded for each location each year. A party is a group of birders travelling together and remaining within sight or sound of each other. Party-miles are the number of miles traveled by all parties on a CBC; if six people travel 100 miles during the day in two cars, the total number of party-miles is 100 if the cars travel together and 200 if the two cars travel separately. Party-hours are the number of hours spent looking for birds. Like party-miles, party-hours are accumulated by groups. If six people travel together for six hours, they accumulate six party-hours; if they split into two groups for two hours, they accumulate four party-hours. Party-miles are heavily influenced by the amount of time spent in a car and seems most useful for species that can be spotted from cars. Party-hours are more useful for birds that are seen and identified on foot. The three measures of effort are all highly correlated (Pearson Product-Moment Correlations (n=21,430 for North America in the years 63-83): observers and party-hours, 0.74; party-hours and party-miles, 0.66; party-miles and observers, 0.61). Because of the high correlations, it should make little difference which index of effort is used for many species. The use of party statistics rather than individual statistics derives from the belief that the number of individual birders in a group has little effect on the probability of detecting individual birds. However, this assumption has not been tested, to our knowledge.

Differences in the Kinds and Amounts of Effort on CBCs

A major problem facing users of CBC data is the fact that there are at least four major ways of looking for birds on a CBC: (1) self-propelled (foot, skiis, bicycle, snowshoes, etc.), (2) motor-powered (car, boat, snowmobile, golfcart, airplane, helicopter, etc.), (3) stationary (at bird feeders), and (4) at night (both self-propelled and motor-powered). The four kinds of effort are reported separately for each CBC location each year; unfortunately, the species and individuals seen are not reported separately. Thus, it is difficult to study the relative abundance of feederbirds or night birds because for these groups individuals are recorded by more than one method. As a result, it is difficult to determine the effect of varying effort on the number of individuals recorded. Therefore, we recommend that birds seen at feeders and birds seen at night be reported separately from birds seen by car or foot during the day.

In addition to the four different kinds of effort, there are wide differences in the amount of effort both within counts among years and among counts within years. The comparison is similar no matter which unit of effort is used; thus, we show differences in party-hours both within and between years (Figures 1 and 2).

In addition, we show changes in party-hours within count locations (Table I). With these great differences in effort, especially within years and over a large number of years, it is vital to consider whether or not effort is affecting the number of individuals reported and to correct for effort if it is.

Possible Relationships Between Count and Effort

Traditionally, the number of individuals seen during a CBC is divided by party-hours or party-miles to create an index of abundance for each species at each location each year (Bock and Root, 1981). This tradition assumes not only that the number of individuals reported increases linearly with effort, but also that the line representing the relationship between count and effort passes through the origin. This is exactly the relationship we found for the Red-tailed Hawk (*Buteo jamaicensis*) (Figure 3).

However, Bock and Root (1981) also noted that there should be some species for which effort has no effect on the number of individuals reported. These are primarily species that occur in habitats that are small enough to be covered in a few hours or less and that are known to be good for birds. Presumably, count organizers send participants to those areas even if there is very little time to count birds. Since the habitat covers a small area, adding many more hours and miles will not add any more time in that habitat; thus, few if any individuals of the species preferring that habitat will be added. For example, we did not find a positive relationship between count and effort for Bald Eagles (Figure 4) and Mallards (Figure 5).

In addition, Johnson (1981) noted that there should be some cases where count increases with effort, but not linearly with a zero intercept. There are two general cases: (1) a linear increase, but nonzero intercept, (2) the rate of increase in numbers declines as effort increases. Species that show these patterns might be more abundant in the small high-quality habitats, but should also be found in lower numbers in other parts of a count circle.

A complicating factor is that the relationship between count and effort varies with a number of variables: habitats, weather, latitude, the relative abundance and conspicuousness of a species in an area, etc. Therefore, every species on every count circle on every count day should have a unique relationship between count and effort. Unfortunately, we only have one data point for each count circle on each count day.

Recommended Steps in Analysis of CBC Data

Despite the multitude of factors affecting the relationship between count and effort, we assumed for this study that the relationship between count and effort is similar for each species within its range throughout the time period of the study. We used the following procedure for evaluating the specific relationships between count and effort:

(1) We included all data for all years from all count

locations that ever encountered the species, and we excluded all count locations that never recorded the species. Thus, we included a lot of zeros from locations that recorded the species only once or a few times in 21 years, but we excluded a lot of zeros from locations that might be within the winter range boundaries of the species but for some reason had never recorded it. The decision of which zeros to include and exclude greatly affects the plot of count versus party-hours or party-miles. However, the only quantity estimated from the plot that is used in our suggested method is the coefficient that governs the slope on the log scale (B, see equation (1) below). This coefficient is only slightly affected by the inclusion of many zeros.

(2) Next we did a linear regression of count versus effort. If the slope were nonsignificant, zero, or negative, we can't say for sure that effort had no effect on the counts, but we <u>can</u> say that other factors were so important that they overwhelmed the influence of effort. For these cases (e.g., Bald Eagle and Mallard; Figures 4 and 5), the number of individual birds reported for each CBC is the best number to use in studies of relative abundance.

(3) On the other hand, if the slope of count versus effort is positive and significantly different from zero, then we recommend correcting the actual number of individuals reported to a number that would be expected if the effort were standard.

(4) The next decision is what that standard effort should be. We recommend choosing a number near the median of the effort

on all counts in the area and during the time period chosen for the study. Choosing a larger number requires too much extrapolation, and choosing a smaller number might minimize differences in counts. For party-hours, we used 50; for party-miles, we used 300.

(5) The next decision is how to model the relationship between count and effort. We have already shown that dividing by party-hours or party-miles is appropriate for some species and that using raw counts is appropriate for others; our challenge was to come up with an appropriate treatment for other situations.

At first we tried a log-log regression, but the results are not completely satisfactory. A major reason is that many species include a large number of zero counts, and log-log regression requires adding a constant to all zero counts. When there is a large number of zero counts, adding the constant distorts the relationship between count and effort.

Our second approach was to fit nonlinear models of the form:

$$(1)\quad CT = e^{A}(PH)^{B}$$

$$(2)\quad CT = e^{A}(PM)^{B}$$

where CT equals count (the number of individuals), A is the intercept on the log-log scale, PH equals party-hours, PM equals party-miles, and B is the slope on the log-log scale. This model is the equivalent of the linear log-log regression, but on the original scale. In addition, this model can be used for the case where count increases linearly with increased effort with a zero intercept by making B equal to 1. We used PROC NLIN in the SAS statistical package (SAS Institute, Inc., Cary, North Carolina) on the Cornell University mainframe computer. We began with a log-log regression to get starting values for the slope and intercept parameters, then we used these starting values to run PROC NLIN in order to develop more satisfactory values for slope and intercept.

From both the log-log regression and the nonlinear model we estimate the two parameters A and B. We decided to use B to transform all actual counts (ACT) into modified counts (MCT) that would be expected if effort were equal. To use B in this way, we had to allow A to vary for each actual count (ACT) and actual effort (APH or APM). We used the following equations:

$$(3)\ MCT = ACT * (50/APH)^B$$

$$(4)\ MCT = ACT * (300/APM)^B$$

where MCT equals modified count, ACT equals actual count, and APH, APM, and B are as before. We derived equation (3) from equation (1) in the following manner: Since we are interested in what a modified count (MCT) would be if there had been a standard effort (50 party-hours), we used the equation $MCT = e^{A*}(50)^B$ (based on equation (1)) where A* is any value that makes the equation fit through the point (ACT,APH) using the B determined for the species. Because $MCT = e^{A*}(50)^B$ (equation (1)), it follows:

$$(5)\ A^* = \ln(ACT) - (B * \ln(APH)).$$

By replacing equation (5) in the modified version of equation

(1), it follows:

$$(6)\ MCT = e\ln(ACT) - (B * \ln(APH))(50)B.$$

This equation is mathematically identical to equation (3), which is the most convenient form for calculating modified counts. The process of deriving modified counts from actual counts is shown graphically in Figure 6. Equation (4) can be derived from equation (2) in the same manner.

These modified counts are now ready for analysis to compare relative abundance through space and time.

Two Case Studies: Northern Goshawk and Black Duck

The Northern Goshawk (*Accipiter gentilis*) is one species where the relationship between count and effort does not fit either of the two classic models (Figure 7). In Figure 7 we show the relationship between count and effort using the nonlinear model and using the log-log regression; we superimpose means from the real data to compare the fit of the two models to the real data. In Figure 8 and Table II we show how our decision about the relationship between count and effort affects our impression of the population dynamics of Northern Goshawks from 1963 through 1983.

The Black Duck (*Anas rubripes*) is another species with an intermediate relationship between count and effort (Figure 9). Figure 9 demonstrates the relationship between count and effort, and Figure 10 and Table II show how our decision about the relationship between count and effort affects our impression of the population dynamics of Black Ducks from 1950 through 1983.

For goshawks, the trend estimate from 1963 through 1983 is essentially the same no matter how the counts are treated (Figure 8; Table II); however, for Black Ducks, there is a dramatic difference in the severity of the decline from 1950 through 1983 depending on how the counts are modified (Figure 10; Table II). The major reason that differences in treatments did not affect our estimate of trends for the Northern Goshawk appears to be the large number of zeros for that species. In most count areas, goshawk numbers varied from zero to one (Figure 11), and this change produced most of the changes in abundance noted. Modifications of these small numbers had little effect. On the other hand, some Black Duck counts were in the tens of thousands (Figure 12). Modifications of these numbers had a large effect on our estimate of the population dynamics of Black Ducks.

Conclusions

(1) Birds observed at birdfeeders and birds observed at night should be reported and analyzed separately from birds observed in the daylight by moving parties.

(2) Analysts should plot the empirical relationship between count and effort to determine if counts need to be adjusted for effort.

(3) If counts increase with effort, then nonlinear regression should be used to estimate the slope of the relationship between the two. Raw counts should be converted to

modified counts that would be expected with standard effort.

(4) After conversion (or a decision that conversion is unnecessary), then standard counts can be used for any studies that compare relative abundance through time or space.

References Cited

Bock, C.E., and T.L. Root. 1981. The Christmas Bird Count and avian ecology. In C.J. Ralph and J.M. Scott, eds., Estimating Numbers of Terrestrial Birds, Studies in Avian Biology 6:17-23.

Johnson, D.H. 1981. Summarizing remarks: Estimating relative abundance (Part I). In C.J. Ralph and J.M. Scott, eds., Estimating Numbers of Terrestrial Birds, Studies in Avian Biology 6:17-23.

Lack, P., ed. 1986. The Atlas of Wintering Birds in Britain and Ireland. T. & A.D. Poyser, Calton, Staffordshire, England.

Table I. Increase in Party-Hours Within Particular Count Locations (1950 - 82)

Time span	Number of locations	% of locations with increase	No statistically significant change	% of locations with decrease
9 - 11	92	28%	68%	4%
15 - 25	302	52%	44%	4%
26 - 33	363	76%	22%	2%

Table II. Proportion of original population present in recent years, calculated from the yearly population indices shown in Figures 8 and 10 (mean of last three years divided by mean of first three years times 100%)

A. Northern Goshawk - 1962-63 through 1982-83

Raw Counts - 292%

Count/PM - 236%

Standard Counts - 243%

B. Black Duck - 1953-54 through 1981-82

Raw Counts - 41%

Counts/PH - 20%

Standard Counts - 28%

Figure 1. This bar chart shows the amount of effort at individual Christmas Bird Count locations in North America during the winter of 1982-83.

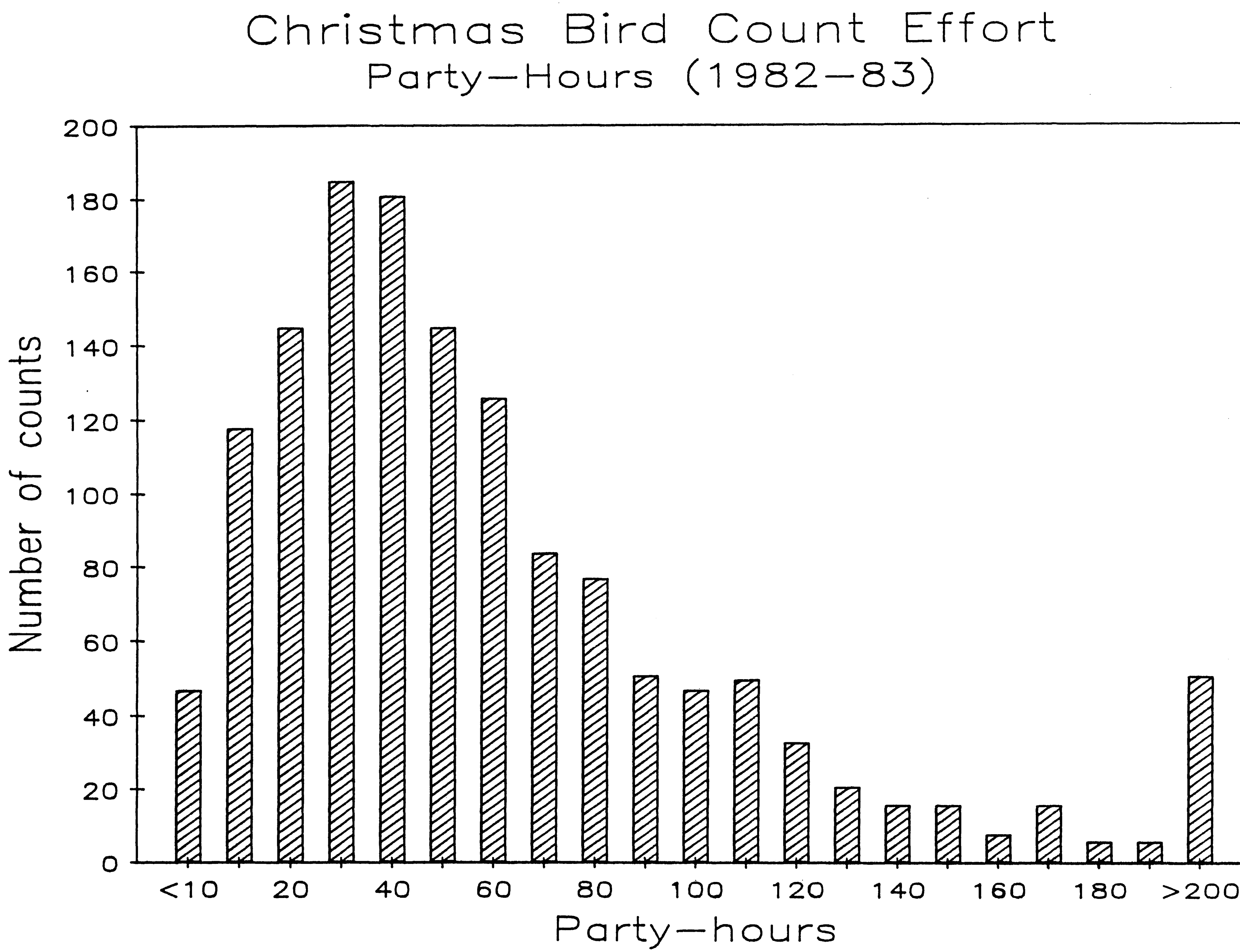

Christmas Bird Count Effort
Party-Hours (1982-83)
Number of counts
0
20
40
60
80
100
120
140
160
180
200
<10
20
40
60
80
100
120
140
160
180
>200
Party-hours

Figure 2. This bar chart shows the mean effort spent on Christmas Bird Counts in North America from the winter of 1962-63 through the winter of 1982-83. Note that the between-year variability for this period is much less than the within-year variability for the winter of 1982-83 (Figure 1).

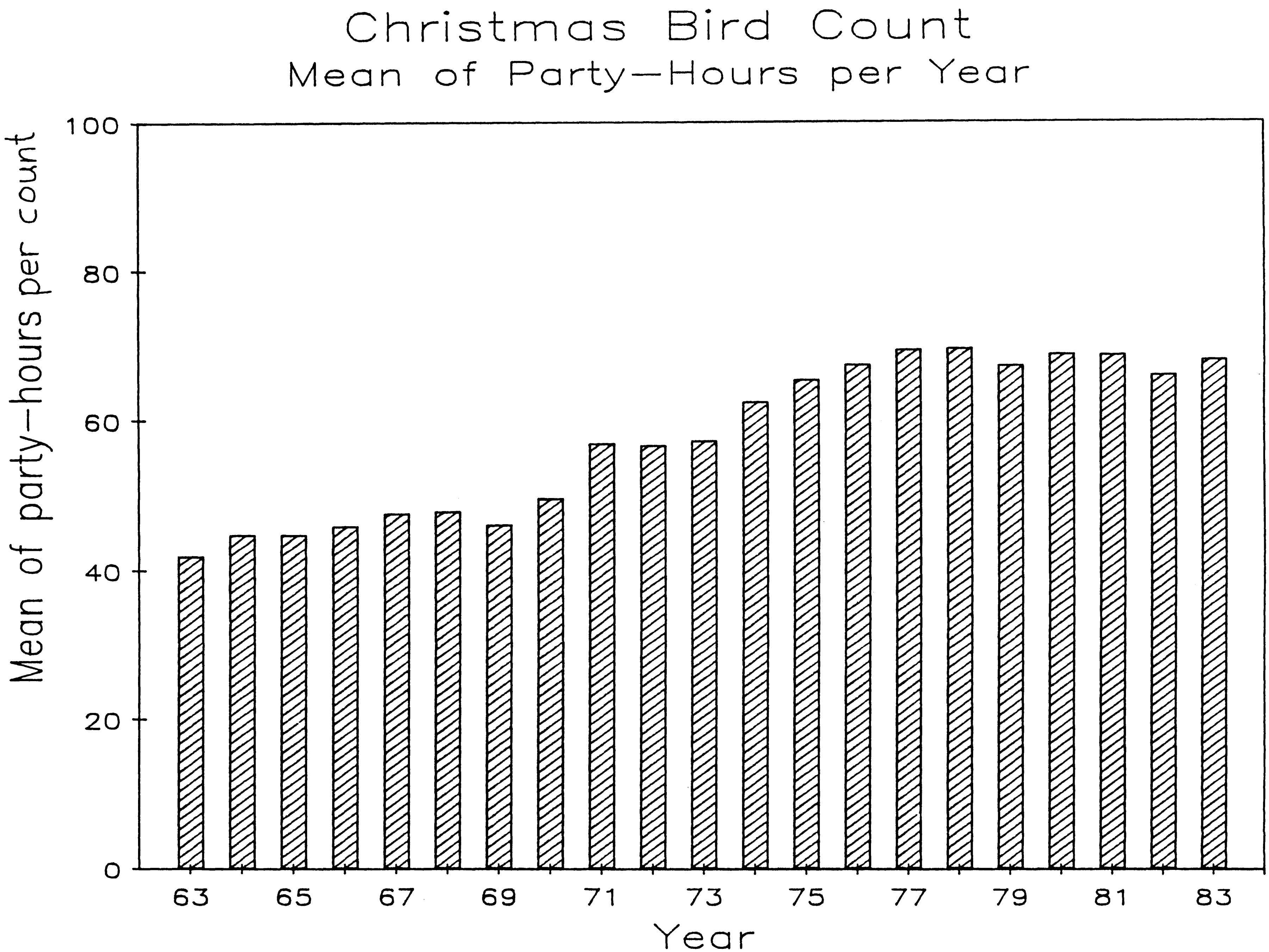

Christmas Bird Count
Mean of Party-Hours per Year
Mean of party-hours per count
0
20
40
60
80
100
63
65
67
69
71
73
75
77
79
81
83
Year

Figure 3. The Red-tailed Hawk showed a highly significant linear relationship between count and effort ($B = 0.007$; $t = 32.0$; $p = 0.0001$) and the y-intercept was nonsignificant ($A = -1.30$; $t = -1.6$; $p = 0.108$). The x's represent means of counts by 10-party-mile intervals using data for all North American locations with at least one Red-tail during one of three years in the early 1970s or three years in the early 1980s. The statistical test used count and party-miles for each location for each of the six years.

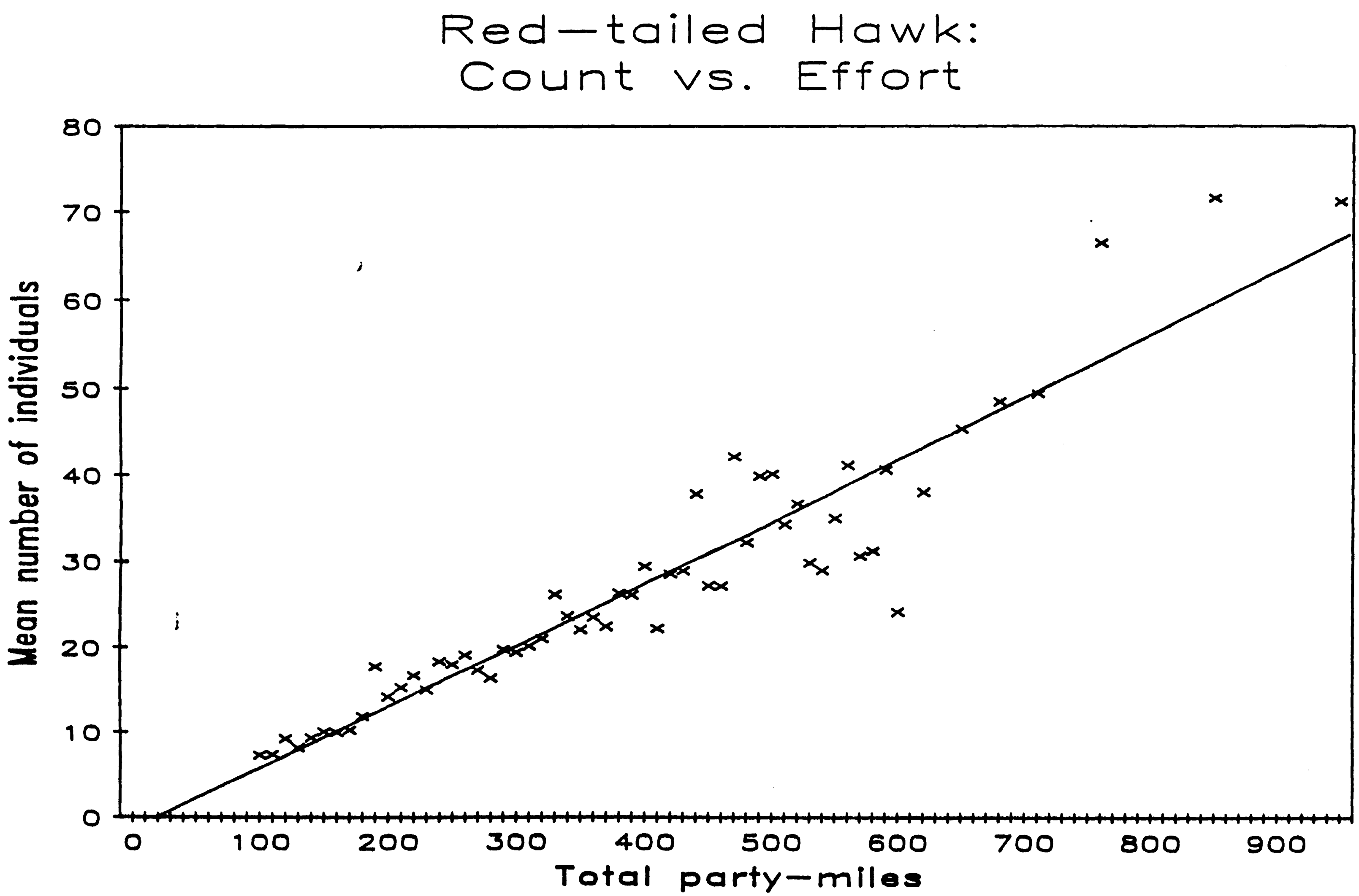
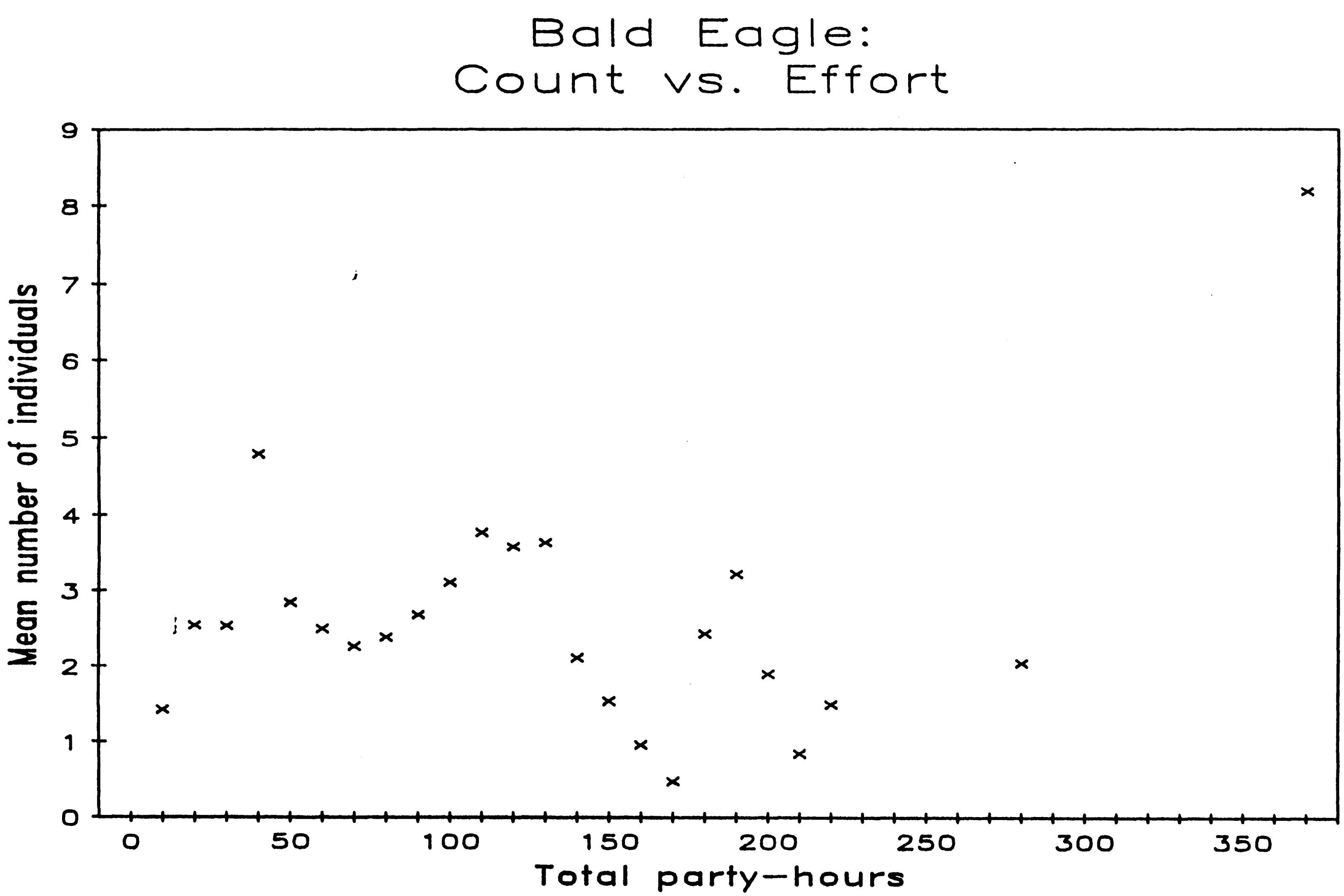

Red—tailed Hawk:
Count vs. Effort
Mean number of individuals
Total party—miles
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
700
800
900

Figure 4. There was no significant relationship between count and effort in the Bald Eagle ($B = -0.063$; $0.05 < p < 0.10$). The data are from three years in the early 1970s and three years in the early 1980s (as in Figure 3).



Bald Eagle:
Count vs. Effort
Mean number of individuals
Total party-hours
0
1
2
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350

Figure 5. There was a significant negative relationship between count and effort in the Mallard ($B = -6.61$; $t = -3.66$; $p = 0.0003$). The data are from the United States and southern Canada east of the 100th meridian from 1949-50 through 1981-82. The negative relationship between count and effort in both the Mallard and Bald Eagle (Figure 4) may be due to the "national wildlife refuge effect": Good wetlands areas are highly valued by birders, thus an area with good wetlands may be chosen as a CBC site even if it is far from urban areas. Such a CBC will have relatively low effort because of its distance from population centers. In contrast, areas near population centers will be chosen as CBC sites and will have high effort even if they lack wetlands.

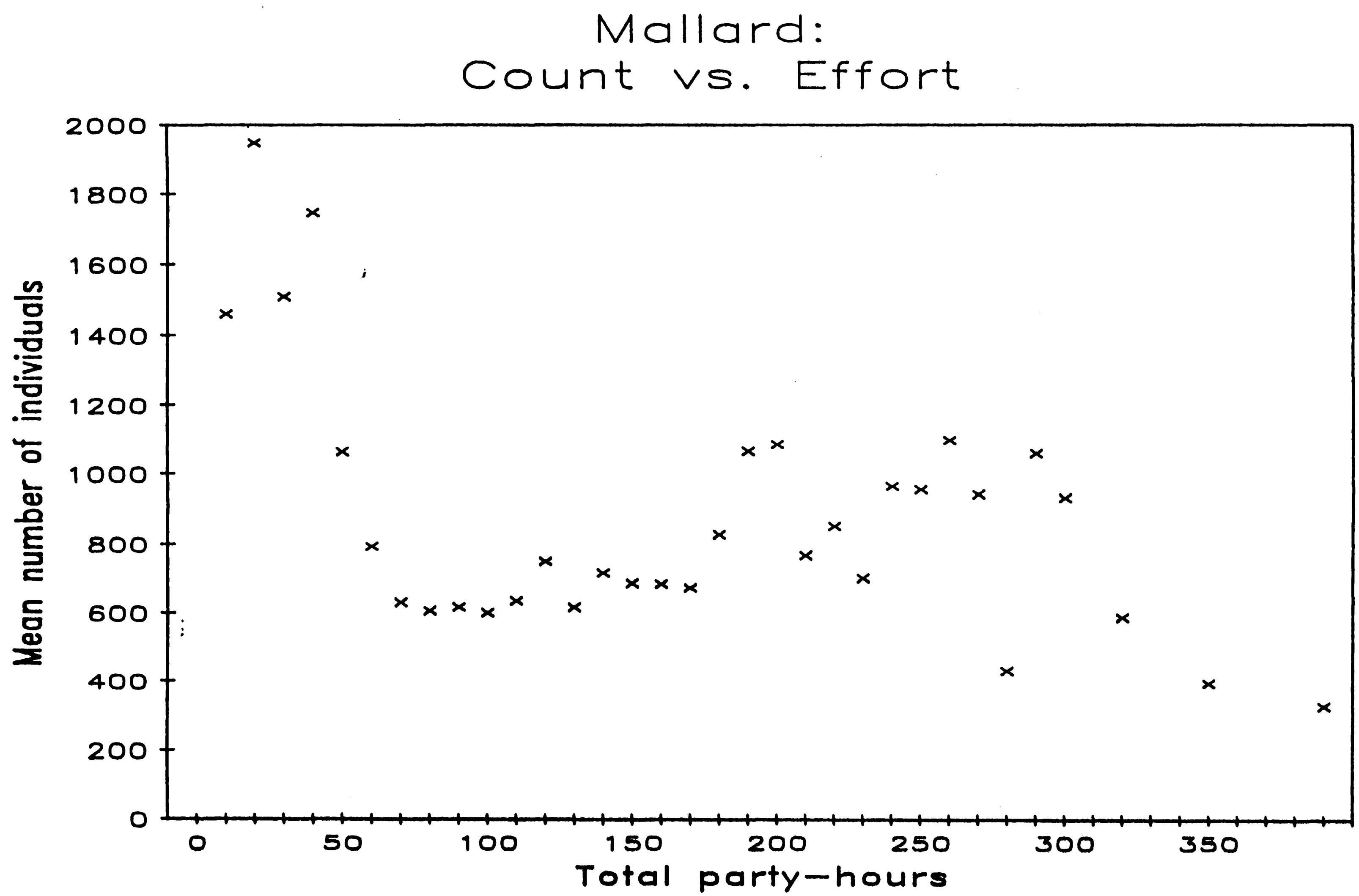
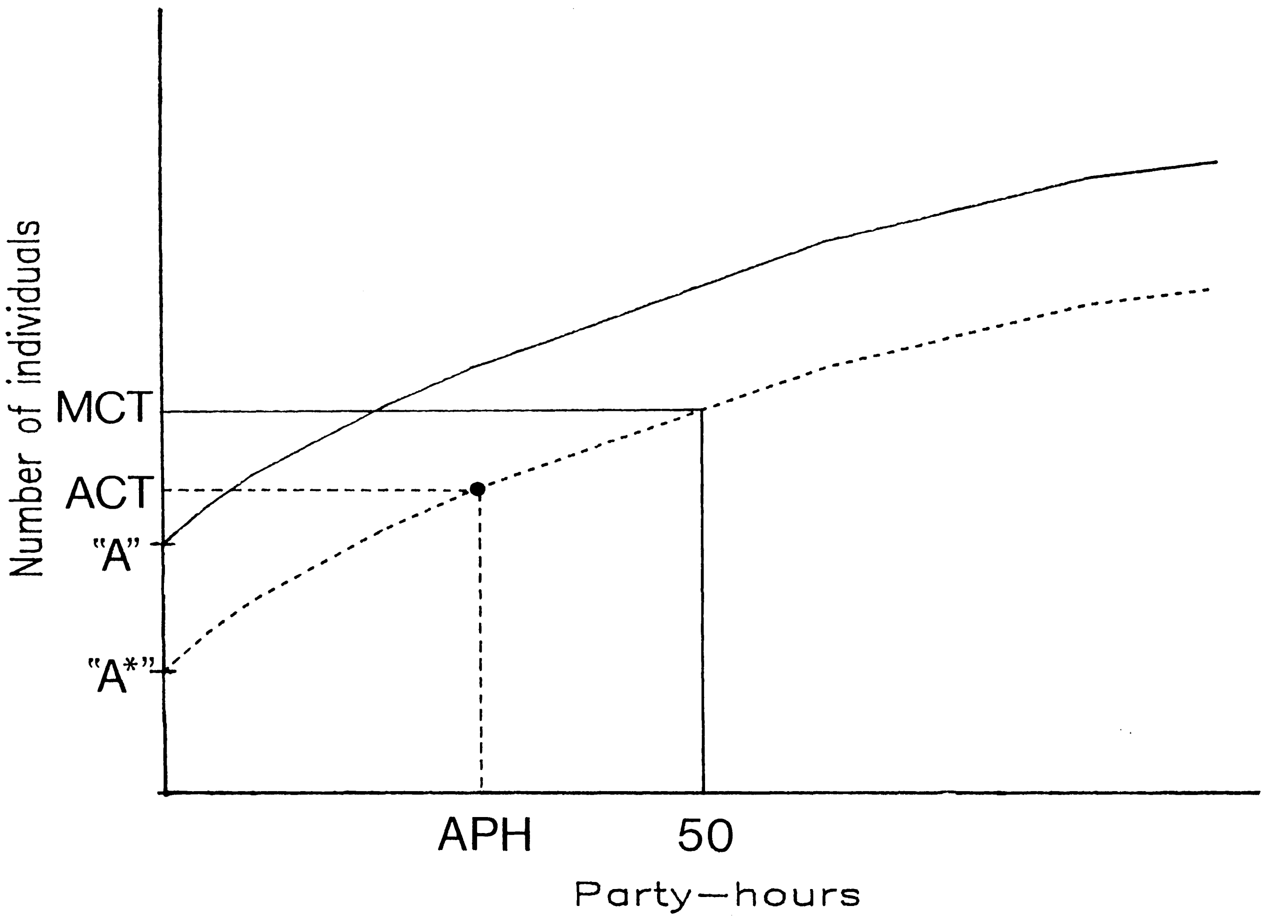
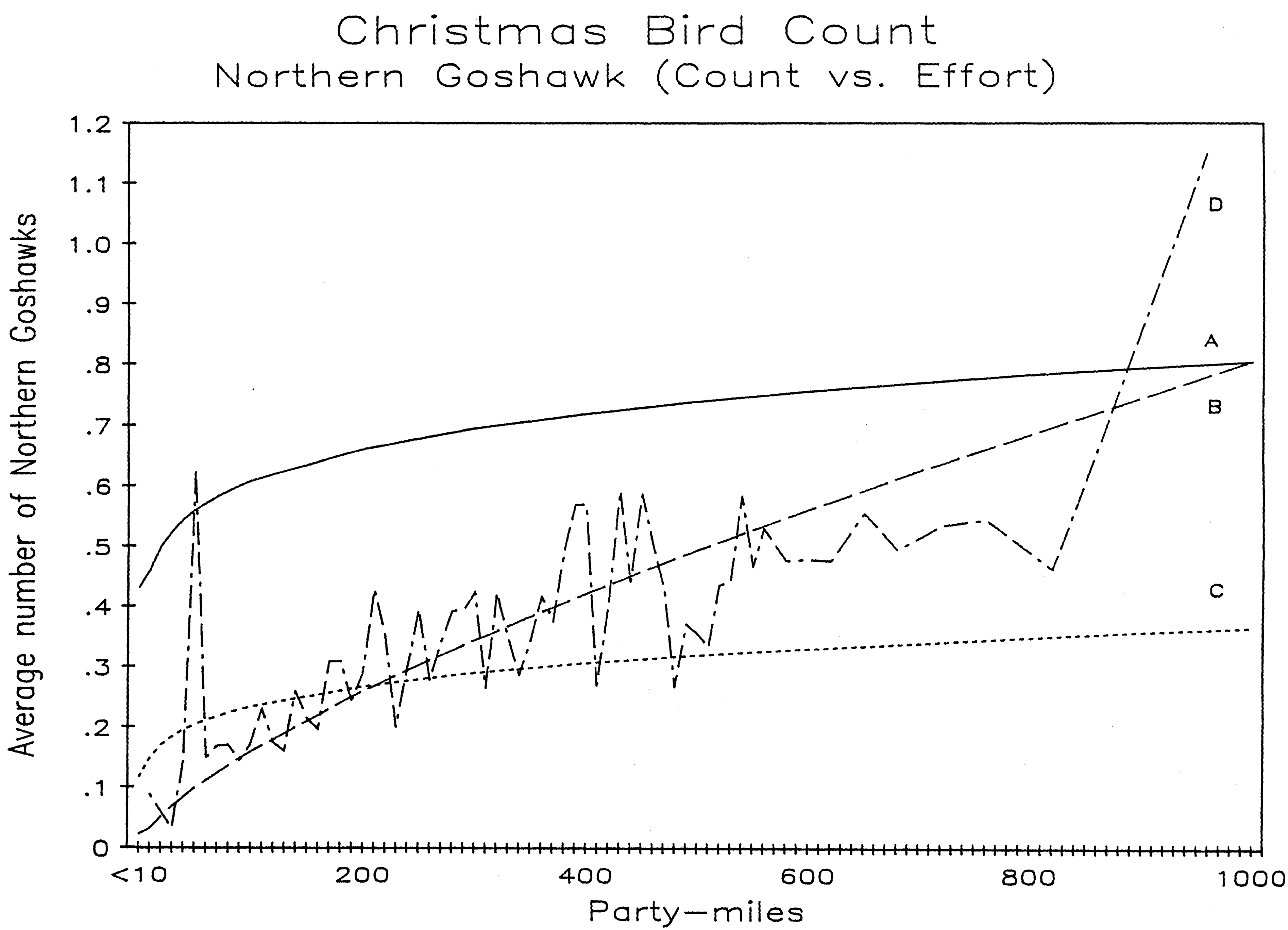

Mallard:
Count vs. Effort
Mean number of individuals
Total party—hours
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
350

Figure 6. This is a graphical representation of our proposed method of creating modified counts from actual counts using a species-specific relationship between count and effort. The solid line represents the empirically-determined relationship between count and effort. The dotted line represents a line with the same "slope" (B), but with a different "intercept" (A*) that allows the line to pass through the actual point for a particular CBC result. The modified count is the y-value for the point where the dotted line intercepts the x-value for the standard count (50 party-miles).



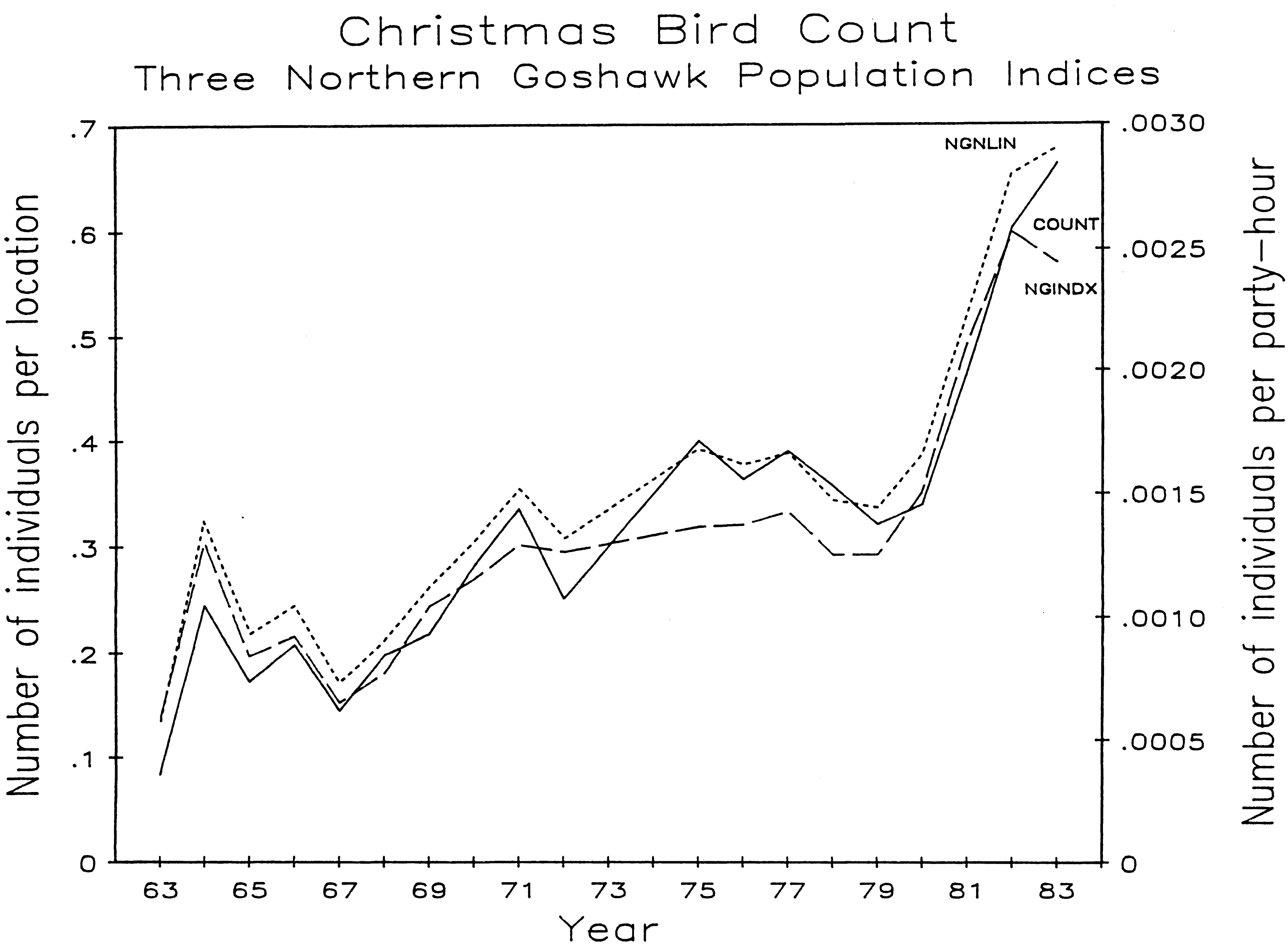
Number of individuals
MCT
ACT
"A"
"A*"
APH
50
Party-hours

Figure 7. Here are four ways to express the relationship of count versus effort for the Northern Goshawk. A represents a log-log regression of count versus effort when a constant of 0.5 is added to all counts. B represents the nonlinear regression. C represents a log-log regression when 1/6 is added to all counts. Finally, D connects all the means of counts per 10-party-mile groups.



Christmas Bird Count
Northern Goshawk (Count vs. Effort)
Average number of Northern Goshawks
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
<10
200
400
600
800
1000
Party—miles
A
B
C
D

Figure 8. Here are three indices of populations levels for the Northern Goshawk. None of the three indices include any modifications for changes in the locations represented in different years. The high counts in the last two years represent major irruptions from more northern wintering areas. The solid line represents the relationship as determined from the raw, unmodified counts (Actual Counts). The dotted line connects data calculated from counts that were standardized using the nonlinear regression (Modified Counts). And the dashed line represents population changes calculated from counts that were standardized by dividing the raw counts by party-miles (Count/PM).



Christmas Bird Count
Three Northern Goshawk Population Indices
Number of individuals per location
Number of individuals per party-hour
Year
NGNLIN
COUNT
NGINDX
0
.1
.2
.3
.4
.5
.6
.7
.0005
.0010
.0015
.0020
.0025
.0030
63
65
67
69
71
73
75
77
79
81
83

Figure 9. Here are four ways to express the relationship of count versus effort for the Black Duck. A represents a log-log regression of count versus effort when a constant of 0.5 is added to all counts. B represents the nonlinear regression. C represents a log-log regression when 1/6 is added to all counts. Finally, D connects all the means of counts per 10-party-hour groups.

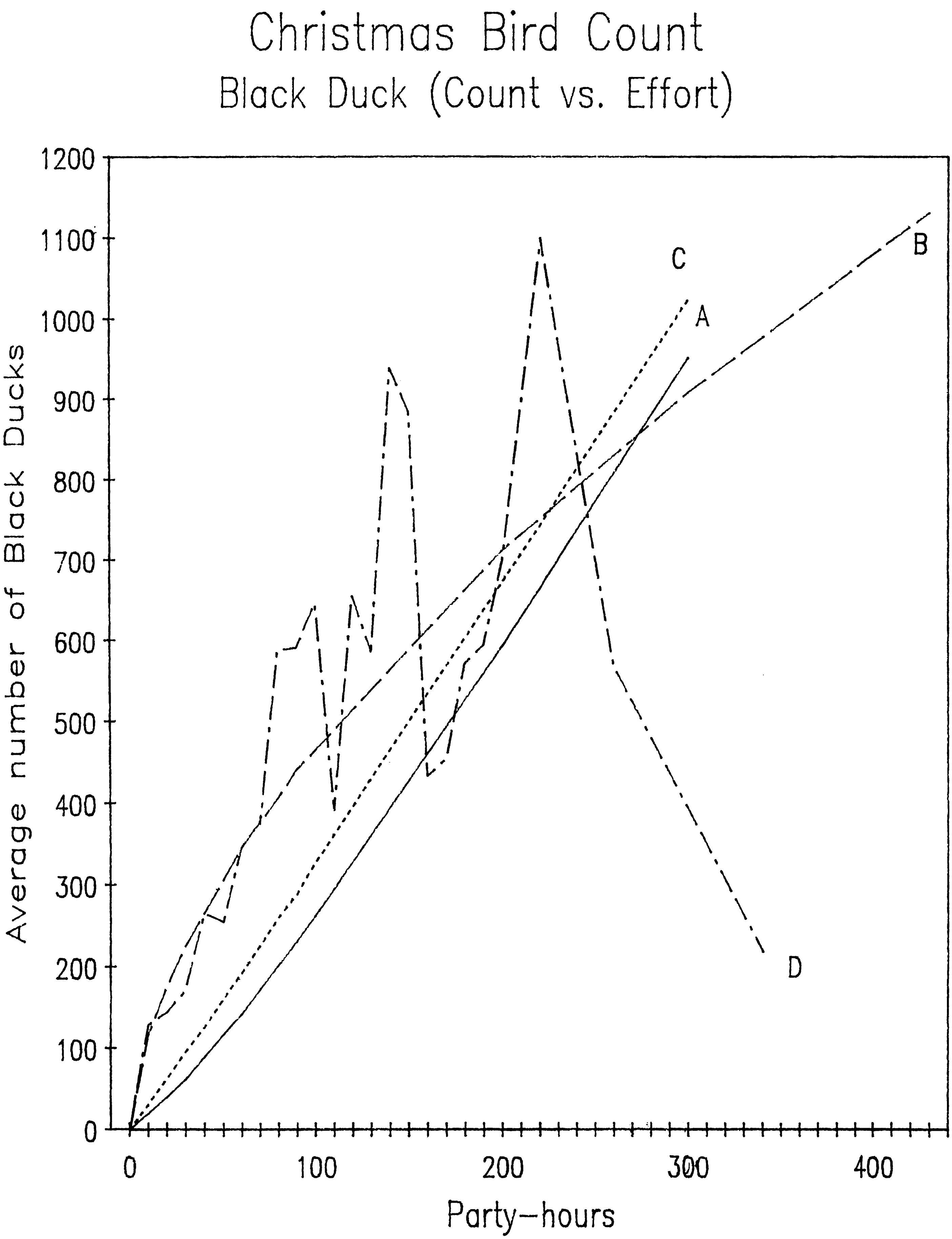

Christmas Bird Count
Black Duck (Count vs. Effort)
Average number of Black Ducks
Party-hours
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
0
100
200
300
400
A
B
C
D

Figure 10. Here are three indices of populations levels for the Black Duck. None of the three indices include any modifications for changes in the locations represented in different years. The solid line represents the relationship as determined from the raw, unmodified counts (Actual Counts). The dotted line connects data calculated from counts that were standardized using the nonlinear regression (Modified Counts). And the dashed line represents population changes calculated from counts that were standardized by dividing the raw counts by party-miles (Count/PH).

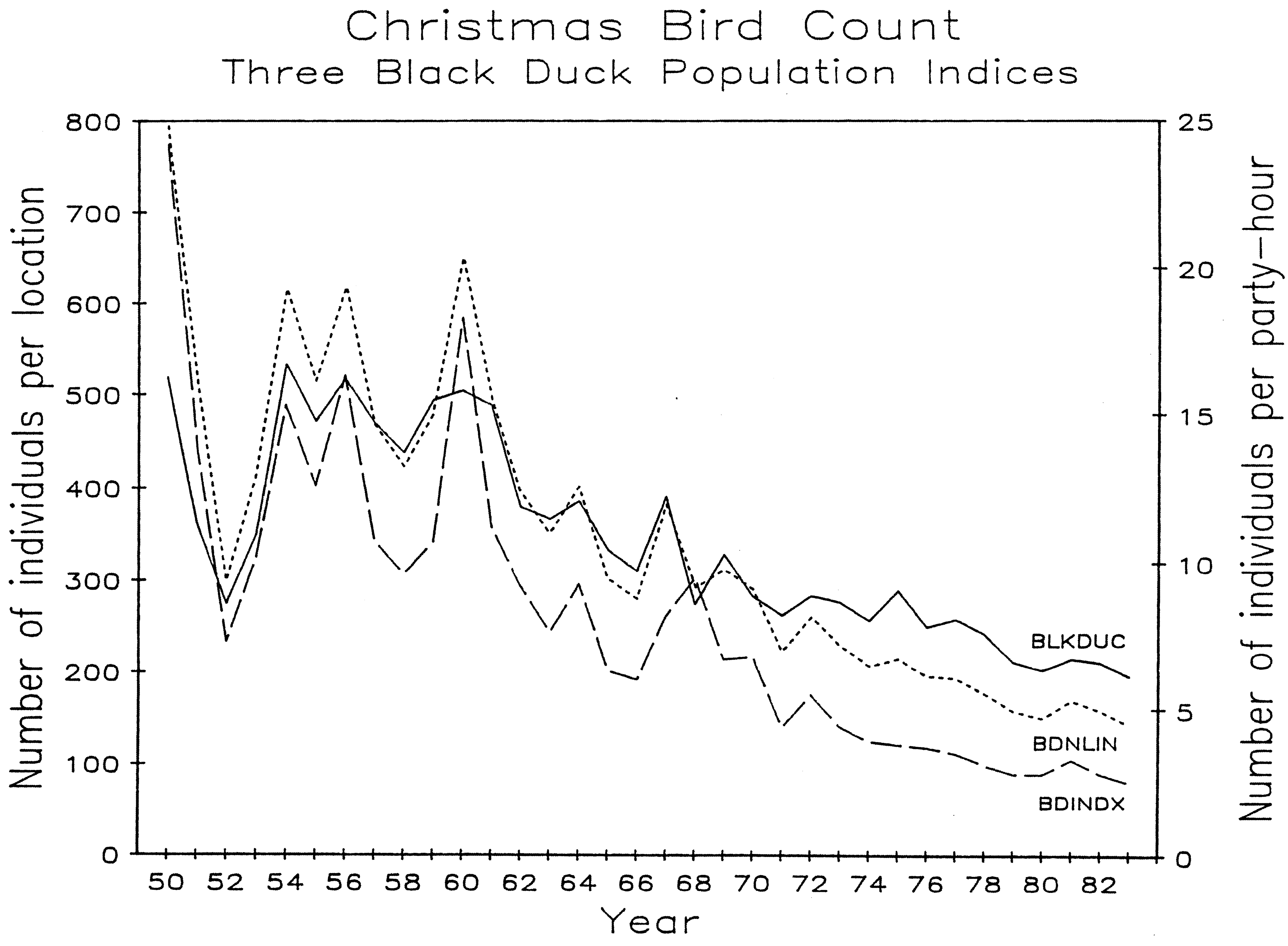
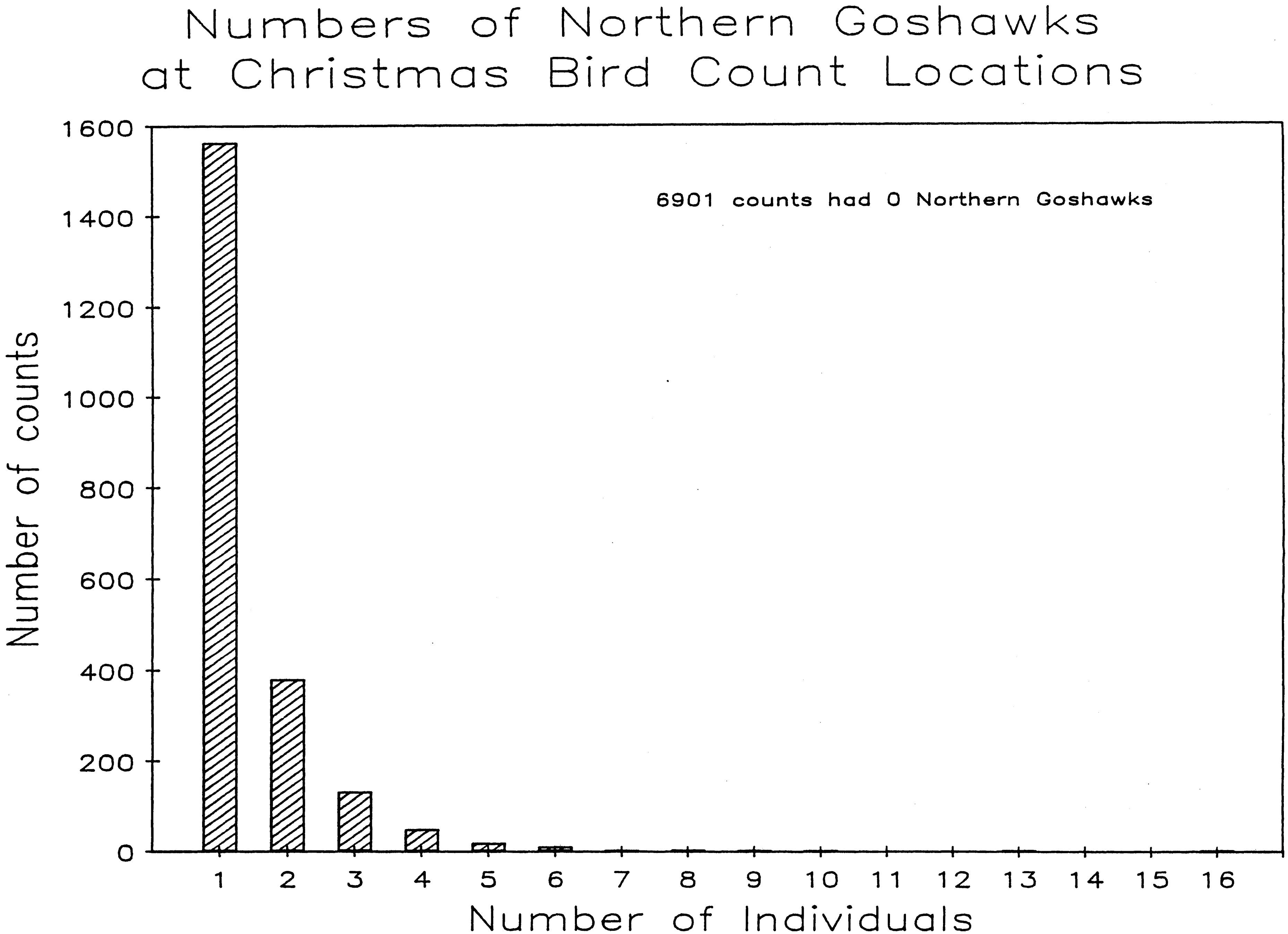
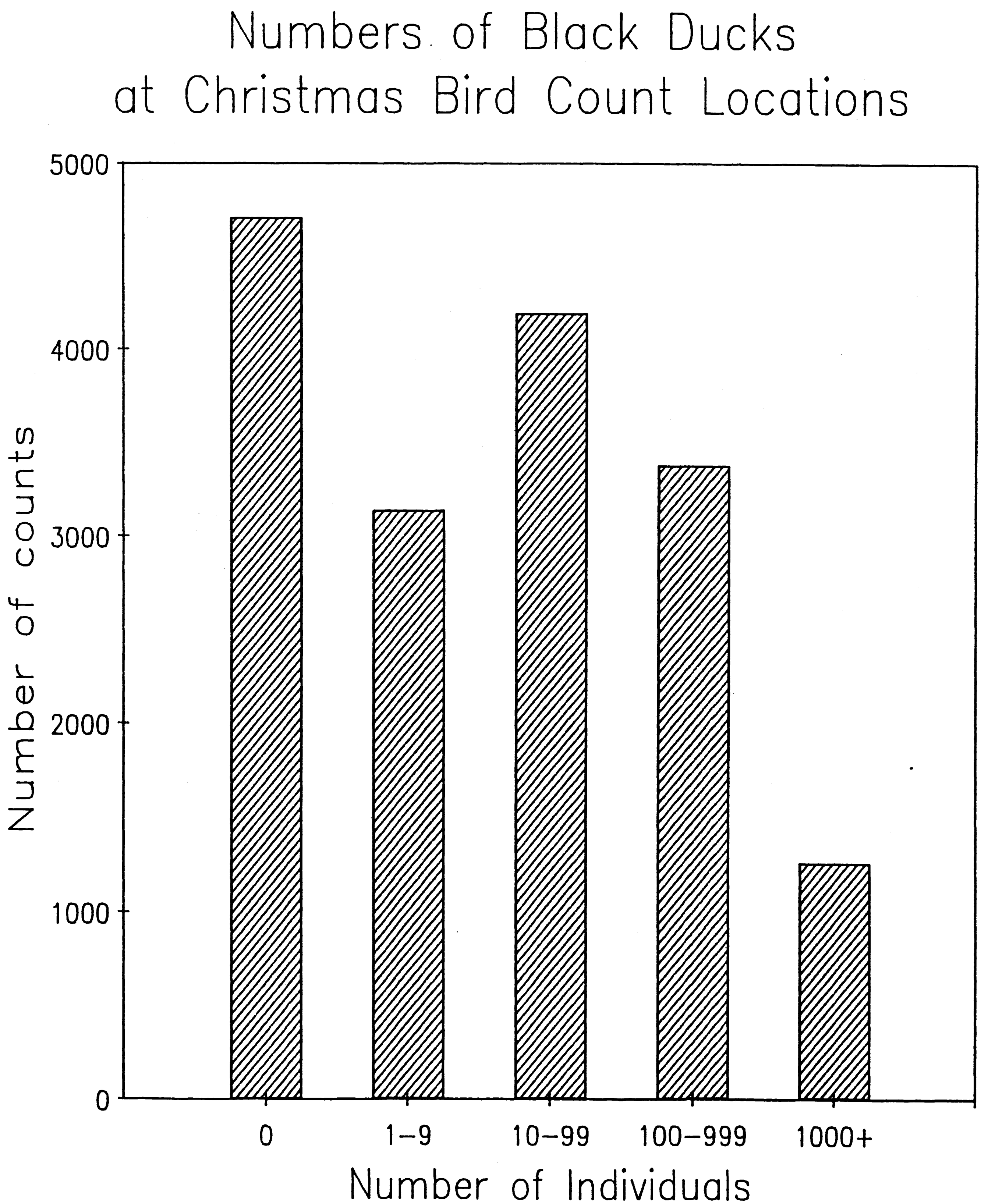

Christmas Bird Count
Three Black Duck Population Indices
Number of individuals per location
Number of individuals per party-hour
Year
0
100
200
300
400
500
600
700
800
0
5
10
15
20
25
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
BLKDUC
BDNLIN
BDINDX

Figure 11. The maximum number of Northern Goshawks reported at any Christmas Bird Count location for any one year (out of three years in the early 1970s and three years in the early 1980s) was 16.



Numbers of Northern Goshawks
at Christmas Bird Count Locations
6901 counts had 0 Northern Goshawks
Number of counts
1600
1400
1200
1000
800
600
400
200
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Number of Individuals

Figure 12. The maximum number of Black Ducks reported at any Christmas Bird Count location in the winters of 1949-50 through 1981-82 was 36,000.


Numbers of Black Ducks
at Christmas Bird Count Locations
5000
4000
3000
2000
1000
0
Number of counts
0
1–9
10–99
100–999
1000+
Number of Individuals